

SPECIFICATION

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METHOD AND APPARATUS FOR DYNAMICALLY SELECTING AN ELECTROCARDIOGRAM COMPRESSION PROCESS BASED ON COMPUTERIZED ANALYSIS OF CARDIAC RHYTHM AND CONTOUR

Background of Invention

- [0001] The invention relates to a computerized electrocardiography system and signal processing therefor. More specifically, this invention relates to the compression of electrocardiographic data for permanent storage and for transmission between an ECG acquisition device and an ECG management system or between two ECG devices.
- [0002] The electrocardiogram (ECG) is a very commonly used, simple, non-invasive test to assess a patient's cardiac condition. Each year millions of ECGs (resting, ambulatory, exercise, bedside monitoring, telemetry, etc.) are collected from patients and are stored on ECG management and cardiovascular information systems. Although ECG records are relatively small in size in comparison with diagnostic imaging modalities such as CT and MRI, the large number of ECGs that are collected and managed in large hospitals can place a significant demand on storage space.
- [0003] The large requirement for storage area generates two significant problems. First, the storage device (such as a disk drive) must be large enough to store a large number of ECGs. Second, and more importantly, the communication devices coupling multiple systems are relatively slow, compared to the processing capabilities of the computerized

systems. Thus, the time required to transmit a large number of ECGs between computer systems can be significant.

[0004] One technique used to solve both of these problems is that of data compression. Utilizing data compression techniques, the storage size of the ECG is reduced. Thus, the ECG utilizes a smaller amount of space in the storage device, and can be transmitted via a communication link more quickly and reliably.

[0005] Two types of ECG compression techniques exist: lossless compression and lossy compression. In lossless compression, the storage size of the ECG is reduced without losing any information in the original data. That is, the ECG can be compressed using lossless compression, stored or transmitted, then decompressed, and the decompressed ECG will be identical to the original ECG. In lossy compression, however, the size of the ECG is reduced and a certain amount of data loss occurs. Thus, an ECG which is compressed, stored or transmitted, and then decompressed will be somewhat different from the original ECG. Although lossy compression causes some data loss, that data loss in most clinical ECGs is either not apparent to the user, or presumed to be inconsequential to cardiac diagnosis. Indeed, lossy compression has been used and appreciated in clinical practice for many years.

[0006] By its nature, the ECG has a high degree of repetition within its data. This repetitive nature has been exploited to develop highly efficient compression schemes. These schemes decompose the ECG into its synchronous (or repeating) and asynchronous (non-repeating) components. The synchronous component of the ECG, typically consisting of a cardiac cycle with its P-QRS-T features, is then reduced to a single representative pattern via averaging or medianization of the sample data. (Not all waves necessarily need to be present in a cardiac cycle. A repeating pattern of QRS-T waves or QRS complexes are occasionally seen in some cardiac rhythms.) The median (or average) P-QRS-T complex is subtracted from the original (raw) ECG data. The remainder, asynchronous component, typically has a narrow dynamic range and lends itself to efficient compression. Given the narrow dynamic range of the asynchronous component, additional compression efficiency can be gained through low-pass filtering, down-sampling and re-quantization of the data. If performed, these last steps render the compression lossy. Both the synchronous and asynchronous components are then compressed using an encoding

scheme such as Huffman encoding. Lossy compression ratios as high as 20:1 have been reported using this method.

Summary of Invention

[0007] The above compression method derives its efficiency from two major premises. One is that the ECG has a large degree of repetition of nearly identical patterns, and two is that the asynchronous component has a narrow dynamic range of voltages compared to the overall ECG data. Both premises, but particularly the latter, are critically dependent on the ability to accurately detect, classify and delineate the repeating pattern within the ECG and certain characteristics of the ECG waveforms. Even a slight imprecision in delineating a particular cycle of the repeating pattern containing high frequency components may leave a high-frequency, large-amplitude pattern in the asynchronous component of the ECG. For example, paced ECGs may leave a large pacing artifact in the asynchronous component at a location where a cardiac cycle was slightly misaligned with the representative cycle. In lossy compression, the amplitude of this narrow pacing artifact can be severely reduced by low-pass filtering, down-sampling and re-quantization causing the reconstructed ECG to be drastically different from the original. In addition, ECGs with high ventricular rates and those with small P waves can pose similar challenges to the lossy compression scheme.

[0008] Obviously, employing a lossless compression scheme would solve the problem described above. However, there would be an approximately three-fold increase in storage requirements if lossless compression was applied universally for all acquired ECGs. This additional storage requirement adds a great deal of expense and is a very high price to pay for solving the problem given that the overwhelming majority of ECGs do not pose any problems with the high-efficiency lossy compression.

[0009] An approach for selecting between lossy and lossless ECG compression is to allow the system user to select between the two methods of compression. Besides the obvious inconvenience to the user, this approach requires a certain level of understanding by the user of which technique works best in each situation. In addition, the speed of the system is decreased due to the decision time of the user. One goal of compression is to increase the speed of data storage and transmission; thus, the time required by the user to select a compression technique hinders attaining this goal.